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ABSTRACT

One cognitive theory of spelling states that the spelling of words can be produced in one of three ways, depending on the amount and kind of information stored in the memory about a particular word. Assuming this theory as a foundation, this study reviewed two forms of computer assisted instruction developed in an effort to build an instructional theory for teaching spelling. One instructional mode stressed memory structure while the other permitted practice in the generation of spelling patterns. A key component in both was the assumption of a phoneme generator, or lists of spelling patterns that are associated with the phonemes they spell. Analysis of the data regarding the children's performance in both programs supports the basic cognitive theory and supplies significant information on the various stages of the learning process: encoding, rehearsal, and entry into long-term memory. (MAI)

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# Studies in Spelling: Theory and Practice*

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Paper presented at the Meeting of the
American Psychological Association,
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# Studies in Spelling: Theory and Practice

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In recent years, cognitive psychologists have become increasingly interested in developing theories of student performance in school tasks such as solving an addition problem, decoding a word and solving an algebra word problem, or a number series problem. To do this, the cognitive psychologist performs a task analysis and describes performance of the given task in terms of the demands the task makes on basic psychological processes such as perception, memory and encoding or recoding processes. The product of this kind of task analysis is a psychological theory of task performance, i.e., a description of task performance in terms of psychological constructs. In this way, complex performances are broken into more basic or elementary components and competence in a task is thought to consist of (a) facility in each component process and (b) facility in combining the component processes in the most effective manner. It is the view of many educational and instructional psychologists that the analysis of school tasks in terms of the constructs of cognitive theories is an important step in attempting to link basic scientific theory to instructional practice. The work reported in this paper represents an attempt to develop and test some of the instructional implications of a basic scientific theory.

The theoretical basis for the research reported in this paper is a cognitive theory of spelling performance formulated by Simon and Simon (1973). Briefly, the theory states that spellings of words can be produced in one of three ways depending upon the amount and kind of information stored in memory

about a particular word. Highly overlearned and familiar words are spelled via direct recall in which the spelling of a word is recalled directly in response to the meaning of the word. Less well learned words, those whose spellings are only partially recallable can be spelled using a generate and test process. In this case, the theory suggests that students use stored information about phoneme to grapheme correspondences to generate a plausible spelling for a word, then use a "test" process in which the trial spelling is compared to stored visual recognition information gained from reading the word to accept the trial spelling or reject it. In the case of words that have not been seen before and for which visual recognition information is not present, students use a direct phonemic spelling process in which information about phoneme to grapheme correspondences is applied to the spelling of the words. In this last case, no test process is activated because there is no stored visual recognition information because the words spelled have not been seen before. The Simon theory has served as the basic theoretical framework for a number of research and development activities in spelling, several of which are reported here.

Instructional programs based on the spelling theory.

The first use made of the Simon theory was to build some instructional programs that embodied processes specified by the theory and then to observe children's performance while working on the programs and measure the effect the programs had on children's spelling behavior.

The instructional programs.

Two different forms of instruction, embodying different aspects of the Simon theory, were developed. One type of instruction tutored children in the memory structure assumed by the theory: children were taught the spelling

patterns associated with particular phonemes, that is, that /Long A/ ---> <A-E>, <AI>, <AY>. The other type of instruction permitted practice in the generate and test process: children were given the chance to spell a given word several different ways, then, on the basis of looking at and comparing the spellings, they could select the one they thought correct. Both kinds of lessons were computerized and ran on Datapoint cathode-ray-tube terminals located at two elementary schools in Pittsburgh, Pa. One school was a suburban public school; the other was a small University laboratory school with only second graders qualifying for use of the program. The instructional strategy of the tutorial program (called SPLPAT for Spelling Patterns) was manipulative and learner controlled, that is, children learned alternative spellings for a sound by first choosing words with a given sound from a larger set; then classifying the words according to the particular spelling patterns that represented the sound in a given word. The generate and test program (called TRYSPL for Try Spellings) permitted the generation of several spellings and the selection of the one spelling thought to be correct. The program then provided informative feedback on the student's choice and displayed the correct spelling.

Management of the programs in the school setting.

Each school used an individualized spelling series. The instructional programs were co-ordinated with the spelling series in a way that spaced usage throughout the year for a particular grade level, yet permitted grades 2 through 5 to make some use of available lessons. There were 16 lessons on SPLPAT and 18 on TRYSPL. Student usage in the suburban school was teacher controlled and maximum usage could result in a child's taking 30% of his spelling work in the computer programs. For the most part, teachers

followed the management and access plan designed by the developers. They felt the computer programs were an integral part of spelling instruction at their school. In the laboratory school, usage was mandatory and only SPLPAT was used.

Usage of the programs in a "naturalistic" setting permitted the collection of extensive data on children's performance on the program. At times, teachers permitted modification of their instructional system to permit the conduct of either more well controlled small scale studies or additional testing.

Database: The suburban school.

Three sets of data form the basis for our studies of children's spelling processes. The data were gathered from records of children's performance on the TRYSPL program. The first sample (Sample 1), taken early in the school year, consisted of twenty-three protocols from eleven fifth graders working on twelve different lessons. A lesson is a list of about 17 words on the average that contain a common sound. The mean grade reading level of these words was 4.5 according to the Carroll (Carroll, Davies, and Richman, 1971) word count. The second sample, (Sample 2) taken later in the year, consisted of forty-four protocols from twenty-eight fourth and fifth graders, where mean reading difficulty over all words was 4.25. Sample 2 is more homogeneous in terms of the children contributing to it; one child had five lessons, one had three, ten children had two lessons and sixteen had one. Lesson content was highly variable in the two samples because the children were located at various places throughout the individualized curriculum. The third sample comes from an experimental study (Block, 1974a) which controlled lesson content and observed the same children across the same lessons. Twelve third

graders took the same three TRYSPL lessons whose mean reading difficulty was 4.75.

Question #1: Concerning validation of the Simon theory: Does the opportunity to generate and test help children to determine the correct spelling of a word?

Recall that TRYSPL permits children to generate as many spellings as they wish, then select the one they think is correct. Children's protocols in Samples 1 and 2 were socred in two ways. The first produced spelling was treated as if it were a child's single best attempt, the one he would produce if he were taking a test, and a percent correct production score was calculated. Then, the data were scored a second time allowing for spellings after the first one. The second scoring was the percent correct choices made from the set of generated alternatives. From the 385 words spelled by children in Sample 1, 145 (38%) contained correct first-produced spellings, while 194 times (50%), the correct spelling was chosen from the set of alternatives. From the 710 words spelled in Sample 2, 284 (40%) were correct first-produced spellings and 391 times (55%), the correct spelling was selected from the alternatives. Both samples show that the multiple choice recognition score exceeds the production score. There is an average gain in figuring out the correct spelling of about 13%, certainly enough to make a practically important difference in a "score" on a spelling test. In Sample 2, the number of times a child's "recognition" score exceeded his "production" score was tallied for all protocols and compared to chance (.5) using the normal approximation to the binomial. The test revealed significant differences ($Z = 3.33$, $P < .0002$).

Block (1974a) also reported an overall average increase in score due to the opportunity to generate and test. It was noted, however, that among the third graders, especially as they worked with words whose mean grade

reading level was above their grade level, there was wide individual differences in children's capacity to profit from generate and test procedures. Some children gained as many as 4 correct spellings through recognition, and others lost just as many by being distracted from the correct spelling due to the presence of alternatives.

In sum, the data indicate that when children are spelling words that they have probably encountered in reading, the use of generate and test can help them determine the correct spelling of a word. These data lend support to a basic assertion of the Simon theory, that some form of scanning and recognition can supplement attempts at recall through the implementation of a generate and test process.* However, when children are spelling words they are less likely to have encountered in reading (as was true of the third grade study), the utility of generating and testing is highly variable and dependent on individual student characteristics. This makes sense in the context of the theory because recognition information is required for successful use of generate and test.

Question #2: Antithesis from principles of instructional design: Does generating alternative spellings depress learning of the correct spelling?

One of the potential "risks" associated with in generating multiple spellings is the chance that incorrect spellings will be learned because they have been generated then looked at during the selection stage. Keeping erroneous spellings to a minimum would be a procedure derivable from principles of programmed instruction. To test this, we intervened with some testing to

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*Note that instructional programs provide only limited control over psychological processes, hence one cannot infer that the basic processes specified by the theory were precisely those used by the child when he constructed, then chose among several different spellings.

make some rough comparisons between achievement on words spelled once vs. several times during a child's work on the TRYSPL program.

The children in Sample 2 were given cassette-led posttests at the completion of their TRYSPL lessons and cassette-led retention tests eight days to two weeks following the lesson. The retention test sampled only half the words learned in the TRYSPL lesson. The children's performance on the post and retention tests was studied as a function of the number of spellings generated for a word on the TRYSPL program. The achievement data are shown in Table 1.

Table 1 shows that the probability of learning and remembering the spelling of a word is not decreased when multiple spellings are generated. The gain in spelling achievement from acquisition to posttest and then to retention test is nearly identical for the two classes of words, those receiving single spellings and those receiving multiple spellings. This finding was also replicated in the Block (1974a) study with third graders. At least in terms of measures of group success, there is no loss of learning due to the generation of multiple spellings.

Question #3: Can children be trained to generate spellings as the Simon model does?

Generating alternative spelling requires knowledge of alternative spelling patterns for a sound, the knowledge structure that the SPLPAT program was designed to teach. If that instructional program is effective and if the task directions of the TRYSPL program ("Use what you know about how sounds are spelled") elicit application of that knowledge to TRYSPL, then we would expect that the alternative spellings generated in the course of working on the TRYSPL program would contain the patterns taught in SPLPAT. In other words, we would expect that once children have acquired the phoneme

generator they would spell exactly as described by the Simon theory in the sense that they use acceptable and plausible alternatives for given sounds.

Presently, we have only a very small amount of data on this question and it comes from the Block (1974a) study. That study showed that prior instruction on SPLPAT did indeed influence the nature of alternative spellings on TRYSPL. Children receiving prior instruction on spelling patterns via the SPLPAT program generated a mean of 1.11 illegitimate patterns (an illegitimate pattern is a spelling pattern that does not spell the target sound, e.g., /OU/ ---> <O-E>), while children not receiving prior instruction generated a mean of 3.55 illegitimate patterns. The data suggested that the SPLPAT program influenced the quality of the alternative spellings, whereby plausible alternatives replace implausible ones. This finding shows that children need to and can be trained to perform spellings as modeled in the Simon theory. As such, these data provide additional evidence that the underlying theoretical analysis can be helpful in understanding the development of competent spelling and, in addition, that the instructional program, SPLPAT, seems to be effective.

The nature of the data presented here, which are basically analyses of selected samples of children's spellings chosen for convenience of analysis rather than cleanness of comparison do not permit the making of strong causal inferences or broad and sound generalizations about the validity of the Simon model, its range of applicability, or the effectiveness of the instructional programs. The sample sizes in some cases are rather small and collapsed over other variables that might influence the nature of trial spellings and accuracy of recognition, such as characteristics of the words spelled or amount of prior experience on the programs and so forth. Thus, more well controlled research with specific attention to other factors that

may influence a "generate and test" process is definitely called for. I would point out, however, that in the development and explication of the theory, few moderating factors were explicitly noted, so in some sense, at least in initial tests of the major tenets, these factors might be ignored.

On the basis of the data presented here, some tentative conclusions can be stated. First, that (a) children's attempts at trying spellings and choosing among them are consistent with a generate and test hypothesis; (b) generate and test is a procedure that is useful in spelling; (c) even though instructional principles might dictate otherwise, generating and testing is a credible instructional idea without inhibiting effects on the learning of the correct spelling, and; (d) with training on spelling patterns, children's "generation" performance conforms more closely to that of an expert who knows the patterns that represent a particular sound. Hence, by learning to use the correct patterns, children have a better chance at coming up with the correct spelling.

Additional research of a pilot nature has been performed with adults to assess their use of generate and test. Eighteen adults listed their spelling demons (i.e., words they'd have to write out and look at or rely upon a dictionary), with troublespots underlined, then were given individualized multiple choice recognition tests. Distractors were formed by varying the spelling pattern in a word's troublespot. Out of 85 words, 72 correct spellings were selected, a choice rate which is significantly above chance and which reflected significant gain in accuracy over first produced spellings. These data provide further support for the "test" mechanism of the Simon theory.

Evaluation of correspondence instruction and the SPLPAT program.

In the laboratory school, research has focused on specifying and

evaluating the effects of extensive training in sound-to-letter correspondences on aspects of spelling performance and achievement in spelling. The laboratory school used two different spelling programs for its second graders, with different programs in different classrooms in different buildings. One program was a typical word list oriented spelling curriculum with minimal attention to sound-to-letter correspondences and optional spellings (Kottmeyer & Claus, 1968). Interview data with teachers using this program revealed they focused their lessons on word lists in the books rather than emphasized correspondence instruction. The other program focused on basic skills training with workbook exercises designed to foster the learning of letter-sound patterns (Botel, Holsclaw, Cammorota, & Brothers, 1971). The SPLPAT program was designed into the latter skills training program and constituted about 85% of a child's spelling training. The computer program delivered spelling lessons throughout the 1975-76 school year and an experimenter was present to manage the instruction in the classroom setting, administer pre and post tests, etc. Determination of the relative effectiveness of each type of basic spelling program is to be done by comparing student performance on an array of pre and post tests, given at the start and end of the school year, to ten second grade students reasonably well matched on entering characteristics. In this study, both the sample size and the design of the study were determined by the fact that computer terminals were located in a single classroom at one site that had ten second graders who could begin spelling instruction.

Data analysis for this study is currently in progress and a full report of the results can be found in a forthcoming dissertation (Thompson, in preparation). Some preliminary analyses are completed and show that the program in which SPLPAT comprised most of the spelling instruction led to the

largest gains in spelling achievement as measured by the spelling component of the Wide Range Achievement Test ($\bar{X}$ pre-post = 13.0 for the SPLPAT group; $\bar{X}$ pre-post = 4.0 for the word list group; ANCOVA $F(1,17) = 16.9$; $P < .01$). The SPLPAT group also gained more on a placement test used with the Botel et al., (1971) series: $\bar{X}$ pre-post = 13.5 for the SPLPAT group; $\bar{X}$ pre-post 1.9 for the word-list group, with total possible correct of 50; ANCOVA $F(1,17) = 19.1$, $P < .01$). Both measures of spelling achievement, the WRAT and the placement test, require children to spell whole words and are scored for number of correct spellings.

Ignoring all the problems with causal inference given this design for a moment, pause to consider this result: the fact that a spelling program that provides training in correspondences with minimal practice on the spellings of whole words can strongly facilitate the number of whole words that children can spell correctly is quite amazing to me. It suggests that training on the way the writing system works is the powerful instructional factor in spelling and the learning of individual facts - the way individual words are spelled - is the wrong place to put instructional emphasis. It ought to be noted also that children's performance on skills prerequisite to spelling - auditory analysis and selected phonetic skills also improved more with the SPLPAT program. This means that prerequisite skills that are required to do the instructional tasks in the computer program are also being developed. Thus, the main ingredients for a good beginning spelling program seem to be the development and continued maintenance of prerequisite basic perceptual skills plus the acquisition of sound-letter correspondences and the concept of optional spellings.

It is again important to note that, in the evaluative study, the experimental and control classrooms differed in many ways, in addition to type of basic program. The results of this evaluative study cannot be neatly

attributed to the type of program factor. Nevertheless, the findings are suggestive of a powerful influence on spelling capabilities that systematic instruction in sound-letter correspondences, as found in the design of the SPLPAT program, may have on spelling process development and spelling achievement. Inferring that the type of instruction in spelling has important effects on the development of spelling capabilities is very reasonable, it seems, despite the absence of good experimental control and representative sampling. A directly analogous result holds in beginning reading with respect to the powerful advantage of systematic instruction in phonics, when that instruction is "properly" designed (see Beck & Block, 1976).

In the evaluative work, we cast the instructional program derived from the cognitive theory into conventional instructional terms, viewing it as systematic instruction in sound-letter correspondences. Then we evaluated the effectiveness of this instructional emphasis in relation to a word-learning emphasis in a fairly traditional attempt at evaluation. For reasons noted above, the design of the study does not meet prevailing standards of evaluative research, which is unfortunate but often happens in CAI research. I am willing, however, to suggest that this finding merits serious attention in future research, for if the findings hold up under more careful study, we may be in a position to revolutionize beginning spelling instruction.

A second aspect of the dissertation study is concerned with a more innovative form of program evaluation, one which is based on hypotheses about the coding and organization of spelling information in memory and how the coding and organization changes with experience on the program. The SPLPAT program requires that children identify words with target sounds, then extract the spelling patterns, and use these patterns as the basis for classifying individual words. At the completion of manipulative exercises,

summarizing verbal descriptions of the relationships between sounds and spelling patterns are provided. It is hypothesized that one outcome of the program is the coding of spelling information at a higher, more formal level. Prior to exposure to the program, children appear to use inductive strategies to figure out the different ways a vowel or consonant can be spelled - they think of words with the sound, write them, then identify the patterns. After exposure to the programs, it is thought that a new kind of structure with a different organization has been formed, enabling more rapid and direct access to spelling pattern information. To test this, pre and post tests are given to each child prior to and after each SPLPAT lesson. The tests are structured in terms of questions of decreasing difficulty. Each question provides an additional prompt. Questions range from high formal (what the different ways the /Long A/ sound can be spelled?) to low concrete (Here are three words that have the /Long A/ sound (examples given). How many different ways can the /Long A/ sound be spelled?). If a given question is not answered within a set time limit, the next (easier) question is given.

Unfortunately, data analysis is not yet far enough along to make any firm statements in regard to the hypotheses suggested. The point to mentioning this work is to simply note that predictions about effects of instructional programs can be derived by referring to basic psychological constructs as one level of analysis and framework for interpretation.

Towards a theory of learning: A contact with methods variables in instruction.

Thus far, the cognitive theory with which we have been working has been used to specify objectives for and activities to be included in an instructional program in spelling. We wanted to push the theory further and understand what it might imply for other design decisions that developers must

make. Of course, the basic theory with which one works must often be developed further so it is relevant to other types of instructional questions. This is precisely what we had to do to make a design decision related to methods of segmenting words for presentation in a computer-assisted spelling drill.

The design decision concerned selecting the best method for segmenting spelling words when presenting them in a computer assisted spelling drill. The choices were (a) presentation in letter-by-letter format, (b) presentation in chunk, or syllable format, or (c) presentation in whole word format. Our interest in the segmentation variable was stimulated by past debates in the instructional literature on the merits of divided vs. undivided methods of presenting spelling words. This design decision required that we think about the nature of spelling learning, rather than spelling performance. In order to use the cognitive theory as a guide, we had to study the performance model and determine what it seemed to imply about learning processes. We used the hypothetical model of learning to develop predictions about the effects of the instructional variable, then tested these predictions in an experiment in which the focal unit of segmentation was varied.

To review, a key component of the Simon theory is the assumption of a phoneme generator, lists of spelling patterns that are associated with the phonemes they spell. We think this implies that during the learning of spellings of individual words, the graphemes must be encoded in terms of the phonemes they represent. It is in fact difficult to think otherwise when it is assumed that spellers learn a phoneme generator. Given the assumption made about the spelling learning process (which in other places we have called the phonemo-graphic encoding assumption [Block, 1974b,), we have one key idea for relating the learning process to the instructional variable.

A way to think about the potential effects of variations in size of the segmentation unit is to consider that, in order for a word to be learned, encoding must be completed, and that visual displays of spelling words where letters or chunks are separated by spaces can make it easy or difficult to complete the encoding process. To show this, one could formulate a flow diagram model of "competent" encoding at a detailed level of perceptual processing, then note how a particular segmented display might either provide external support for steps in processing (in which case encoding would be facilitated) or might require additional processing to compensate for a display that is not adaptive to encoding processes (in which case encoding would be disrupted). In essence, this theorizing entails determining how the instructional variable interacts with the learning process. This is the strategy we followed for building a theoretical analysis of the instructional variable and generating differential predictions as to its effects.

A complete report of the theory and findings can be found in Block et al., (1974). It will suffice to say that the predicted effects were obtained, a finding that provides indirect support for the hypothetical analysis of the interaction of the word display variable and the encoding processes. I think that these are two important points associated with the conduct of this research that are worth mentioning. The first is that in our theoretical analysis we attempted to make explicit the assumptions made about the encoding process so that the validity of these assumptions might be established by basic research. The second is an important point about the research apparatus; the experiment was carried out in a more well controlled setting, i.e., in the context of a computer assisted spelling drill. This kind of instrumentation provides better control over a students learning process and makes it plausible that our rather detailed theoretical analysis

of the events in learning was a reasonable description of the way learning might actually proceed. It would seem that instructional instrumentation that provides more precise control over moment to moment events in learning would be essential to the conduct of experiments whose theoretical rationale is based on fine grained analyses of the learning process that are the products of laboratory research in learning.*

An important requirement for further experimentation on instructional variables in spelling is further development of the theory of learning to deepen understanding of the various stages, encoding, rehearsal and entry into long term memory. In another study (Blumberg & Block, 1975) we examined the effects that a different instructional variable had on the learning process and were able to suggest that it seemed to influence the completion of the encoding process. We are, however, eager to widen our understanding of the instruction/learning process beyond our analysis of its initial stage. A complete theory of learning must be hierarchical in form and incorporate mechanisms for the learning of generalizations and spelling rules that are based on relationships between words. To some extent, existing theories (for example, those used in the Fishman et al., (1968) study) are sufficient for some instructional applications, but additional theoretical development will be required for others. It is hoped that the kind of work we report in this paper will encourage additional work on the kinds of problems we have addressed here.

Summary and conclusions.

In this paper we have attempted to show by the use of examples from our

*I am indebted to my colleague Charles Perfetti for noting the important requirements on instrumentation for instructional experiments based on learning theory analyses.

work in spelling the methods by which we think an instructional psychology gets built and we have outlined some of the theoretical and methodological issues entailed in its development. A fuller treatment of this topic is available in Block (1974b). On the basis of these studies and the theory that generated them, it can probably be said that an instructional theory which has as its basis an underlying cognitive theory is currently emerging in the subject area of spelling. This theory is qualitatively different from those of Thorndike's era in that it is based on constructs of cognitive psychology applied to analyze and specify in detail aspects of spelling learning and performance. The work reported here, although very limited when the full scope of problems that are a concern of instructional theory are considered, is, nevertheless, an example of an important kind of effort in which more and more educational psychologists might be expected to engage.

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Table 1. The probability of a correct spelling on a post or retention test as a function of a number of spellings generated on the TRYSPL program.

| Number of TRYSPL Spellings | Number of Words | TRYSPL percent "Correct" | Posttest percent Correct | Number of Words | Retention test percent Correct |
|---|---|---|---|---|---|
| One | 495 | 57% | 84% | 238 | 85% |
| More than one | 215 | 50%* | 84% | 125 | 89% |
| TOTALS | 710 | | | 363 | |

*When multiple spellings were generated on the TRYSPL program, 50% of them contained the correct spelling as a member of the set.